arXiv:astro-ph/9703165v1 25 Mar 1997

INTRODUCTION & OVERVIEW: CMB SESSIONS

G.F. SMOOT
Lawrence Berkeley National Laboratory,
University of California, Berkeley CA 94720, USA

This is a very exciting time for the CMB field. It is widely recognized that precision measurements of the CMB can provide a definitive test of cosmological models and determine their parameters accurately. At present observations give us the first rough results but ongoing experiments promise new and improved results soon and eventually satellite missions (MAP and COBRAS/SAMBA now named Planck) are expected to provide the requisite precision measurements. Other areas such as observations of the spectrum and Sunyaev-Zeldovich effect are also making significant progress.

1 Introduction

There has long been anticipation that cosmic microwave background (CMB) radiation would provide significant information about the early Universe due to its early central role and its general lack of interaction in the later epochs.

1.1 COBE

Though there have been many observations of the CMB since its discovery by Penzias and Wilson [1] in 1964, the Cosmic Background Explorer satellite, COBE, provided two watershed observations. The first key observation is that the CMB is extremely well described by a black-body spectrum [2,3]. This observation of the CMB thermal origin strongly affirms the hot Big Bang predictions and tightly constrains possible energy releases, ruling out explosive and other exotic structure formation scenarios. The spectral measurement of the temperature as a blackbody and the dipole anisotropy as its derivative provides the basis of knowledge of the spectral shape of the higher order CMB anisotropies and thus a means to separate them from the foregrounds.

The detection of primordial CMB anisotropies [4] is the second key from COBE. The COBE large angular scale map of the microwave sky and detection of intrinsic anisotropies provides support for the gravitational instability picture and thus a link to large scale structure, an anchor point in the magnitude of fluctuations, an impetus and guidance to the field as a whole.

1.2 Theory

In addition to the increased attention to observations and the development of experimental techniques, a major thrust in the field has been the improvement in theory and ideas for extracting information from the data. Theoretical work has provided ideas and means to calculate the observable effects of various cosmological scenarios from standard Cold Dark Matter (sCDM) and its variants, various inflationary models through to nearly a good description of topological defects (an area still in active development). Other work has lead to a better physical intuition of the mechanisms involved [5,6,?].

The inverse problem of extracting the scenario and the appropriate cosmological parameters including error estimates is an active area following the pioneering paper by Llyod Knox [7] and a seminal paper by Jungman et al.[8]. The understanding that one can extract cosmological parameters with accuracy is now driving the excitement in the field in equal measure with the knowledge that the CMB anisotropies are there and are observable.

2 Current Observations

Since the COBE DMR detection of anisotropy, over a dozen groups have reported anisotropy detections and some interesting upper limits. The current power spectrum observations are summarized in the left panel of Figure 1.

For comparison the right panel shows the predicted anisotropy power spectrum for a number of different cosmological models.

3 Future and CMB Sessions

The CMB field is extremely active and exciting precisely because of the combination of rapid observational and theoretical development with definitive space missions in the coming decade and of the expectation that those observations will provide us with accurate determination of cosmological parameters. The great progress and interest are shown by the coverage in the invited talks by Scott Dodelson [9], Lyman Page [10], and Neil Turok [11] and in the talks in these two CMB sessions as well as posters and discussions by the meeting attendees.

A large total effort is necessary to achieve these lofty aims. The many people in the field must work together in a combination of competition and collaboration. Collaboration is necessary because the tasks are large and difficult as well as subtle. Competition is necessary as many people, especially the large number of young and very excellent scientists, must continue to establish their careers and accomplishments and because some competition is useful to keep eveyone on their toes. However, it is important to keep in mind that our

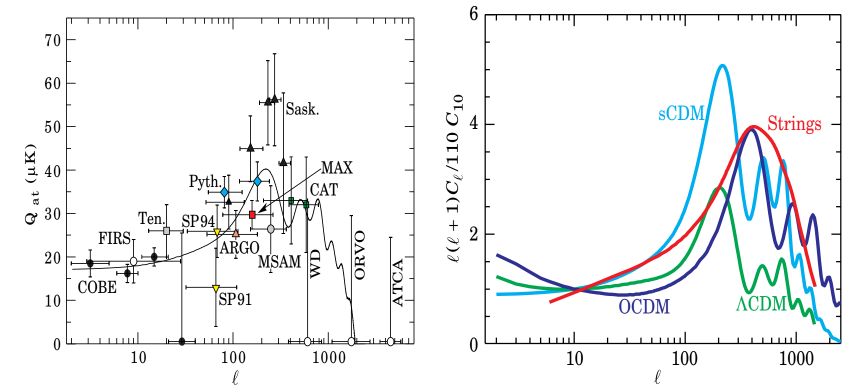

Figure 1: **Left Panel:** Current CMB anisotropy power spectrum observations. The horizontal axis ℓ is Legrendre polynomial number and is inversely proportional to the angular scale. The vertical axis is the RMS (rather than power) temperature variation for that angular scale. The solid curve is the calculated anisotropy for sCDM. **Right Panel:** Theoretical CMB anisotropy power spectrum for various models. The vertical axis is the temperature anisotropy power for that angular scale.

ultimate goal is the accurate testing and determination of cosmological models and parameters and that transcends any one group. The total resources that are and will be allocated to this effort are temendous - both in financial and human capital terms. It is everone's responsibility to work towards this ultimate goal and especially for the senior scientists to promote this and set a tone of friendly and helpful competitive cooperation. The rapid open sharing of data is a good standard but more is needed.

In addition to this cooperation a number of things must fall into place. The first is outstanding instrumentation and techniques for making the observations. Quality instrumentation is particularly important for the forthcoming satellite missions as they are costly in terms of money and mission opportunity.

The next is an understanding of how to process the data and then to turn the calibrated data into maps, power spectra, and other useful forms. This is intimately linked to understanding both the instruments and the foregrounds: galactic and extragalactic including the SZ effect. Work is needed in this area and has begun.

Finally the calibrated separated data must be used in the inverse problem to test cosmological models and recover their best-fitted parameters.

All of these efforts require a significant advancement in their technology. The talk by John Carlstrom [12] on making Sunyaev-Zeldovich maps using new technology HEMT (high electron mobility transistor) amplifiers is an example

of the advances that can be made in a field with new techniques/technologies. We have only recently come to appreciate the computorial complexity of utilizing a million-plus pixel map. Already a number of approaches are being tried and programs being developed to address these issues.

The existence of already ongoing programs, e.g. the balloon-borne instruments: BOOMERANG/MAXIMA, MSAM/TOPHAT, HACME/BEAST, and the interferometers: VCA, CBI, VSA, will provide additional and appropriate data to test these techniques in a very short time horizon. These plus the pressure from the future missions and observations provide us with both an exciting and challenging field.

Acknowledgments This work is supported in part by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

4 References

1. A.A. Penzias and R.Wilson *Ap. J.* **142**, 419 (1965).
2. J. Mather *et al Ap. J.* **420**, 420 (1994).
3. D. Fixsen *et al Ap. J.* **424**, 1 (1996). astro-ph/9605054
4. G.F. Smoot. *et al*, *Ap. J.* **396**, 1 (1992).
5. W. Hu & M. White *Ap. J.* **xx**, 1 (1996). astro-ph/9609105, 9609079, 9604166
6. A. Albrecht *et al*, *Ap. J.* **xx**, 1 (1996). astro-ph/9612017
7. L. Knox *Phys. Rev.* D **D52**, 4307 (1995). astro-ph/9504054
8. Jungman*et al*, *Phys. Rev.* D **54**, 1332 (1996). astro-ph/9512139
9. S. Dodelson, These Proceedings "CMB Theory" 1997.
10. L. Page, These Proceedings "CMB Experiments" 1997.
11. N. Turok, These Proceedings "Early Universe" 1997.
12. J. Carlstrom, These Proceedings "SZ Observations" 1997.